# THE RELATION OF WEATHER TO THE DATE OF PLANTING POTATOES IN NORTHERN OHIO


OHIO

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*BULLETIN 399*


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## CONTENTS

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# BULLETIN

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## THE RELATION OF WEATHER TO THE DATE OF PLANTING POTATOES IN NORTHERN OHIO

JOHN BUSHNELL

### INTRODUCTION

Planting of late varieties of potatoes in northern Ohio extends from early April to late June, a period of more than two months. This unusual situation is due to the fact that, with a growing season two months longer than the late maturing varieties require, no definite period within the two planting months is as yet generally recognized as the best time to plant.

In a few localities in the northern half of the State, the planting period has narrowed down to what may be termed local standard practices. However, these local practices are not uniform thruout northern Ohio. In the important production centers they fall into two distinct categories, (1) April planting and (2) June planting. In both cases Rural varieties are grown. The widespread diversity in time of planting has led to some confusion, which is reflected in the contradictory statements found in the literature.

Statistics on date-of-planting potatoes are collected by the U. S. Bureau of Agricultural Economics. Two brief summaries of these statistics have been published to date, but in these reports no attempt has been made to distinguish between those regions where planting is restricted to a brief period and those, like Ohio, where planting spreads over several weeks. It is particularly interesting that the two summaries do not agree as to time of planting in northern Ohio. Smith (37) in 1915, showing the time of planting in the United States by isochronal lines, included all of northern Ohio in the zone in which planting takes place between June 1 and 15. Two years later, Baker, Brooks, and Hainsworth (2), with a larger number of reports at hand, using the same method of presenting the data, showed that in northern Ohio potato planting was "most general" during May. One might conclude from the discrepancy in the two reports, that in some seasons the peak of planting came in June and in other seasons in May.

Whatever the explanation of the difference between these reports may be, there is little doubt that planting extends thru both May and June—a fact usually recognized by Ohio writers. Thus, Green and Green in 1913 (16) stated that "main plantings in Ohio are made the last week in May and the first part of June and continue until the first week in July". Later, one of these writers (Green, 15) recommended planting during the first two weeks of May. More recently, Glines (14), describing current practices, reported that "planting is usually not made until the middle to the last of June, tho when an earlier crop is desired plantings are sometimes made in May".

In addition to the plantings of May and June, there is the localized practice of planting Rural varieties in April. Taken as a whole then, in current agricultural procedure, late varieties are planted thru the three months of April, May, and June.

The primary aim of the present study has been to determine and evaluate the more important factors influencing the time of planting, and thus to derive practical recommendations.

Field experiments on time of planting potatoes have been carried on at Wooster for six years. Similar field experiments have been reported from other experiment stations where the problem is similar. In addition to this direct evidence from field experiments, there is considerable information on the fundamental aspects of the problem in the literature dealing with the effect of weather on the potato crop. An ultimate analysis of the date-of-planting problem, at least in the yield aspect, must be based upon the reaction of the crop to the various factors encountered during its growing period. The problem therefore may be analyzed from the ecological viewpoint of the relation of time of planting to the factors affecting yield.

In Ohio, the important ecological factor which varies with the date of planting potatoes is weather. The time of occurrence of insects and diseases is also a consideration, but as these pests become more and more successfully controlled by seed certification and spraying, the time of planting becomes essentially a problem of fitting the growing period of the crop to the most favorable weather.

From the weather standpoint the problem may for convenience be divided into (1) a study of the reaction of the crop at its various stages of development to different weather conditions and (2) a study of the climate with reference to the requirements of the crop. These fundamental aspects have not been emphasized in the literature on time-of-planting, therefore it seems advisable to treat them in some detail here.

## REVIEW OF LITERATURE

### EFFECT OF WEATHER ON THE POTATO CROP

**Temperature.**—Temperatures such as occur in Ohio during the summer months are generally conceded to be far above the optimum for the best development of the potato crop. In a recent bulletin the writer (6) reviewed the literature on this point and concluded (1) that the optimum temperature for yield is near 64° F. and (2) that the low yield per acre, characteristic of much of the agricultural region of the United States, is in a large measure a result of high summer temperatures. This evidence points to summer temperature as an important limiting factor in potato yields in Ohio.

High temperature therefore must be given primary consideration in the date-of-planting problem. In this aspect the problem becomes an attempt to so adjust the date of planting as to minimize injurious effects of summer temperature. Then at once the question arises, Does the crop have a period when it is more sensitive to temperature than at other times? If so, at what stage of development?

The sensitive stage, according to the evidence in the literature, is the period of tuber development. At least, tuber growth is more affected by unfavorable temperature than is growth of the aboveground parts. The difference in sensitivity is illustrated in the experiments of Jones, McKinney, and Fellows (22), who grew plants at different soil temperatures and found that the tubers grew most rapidly at 18° C. (64.4 F.) while the tops made their greatest growth at 21° C. (69.8 F.). What is more important in their experiments, the decline in the rate of growth of the tubers at the higher temperatures was very conspicuous. At 27° C. (80.6 F.) the yield was less than half of that at 24° C. (75.2 F.) (Fig. 1). In an experiment conducted by the writer (Bushnell, 6), in which the air as well as the soil temperatures were controlled, the difference between the reaction of the tops and of the tubers was even more striking (Fig. 2). At 29° C. (84.2 F.) no tubers formed. The results of these two experiments with plants in partially controlled environments show convincingly that the growth of the tubers is more retarded by high temperature than the growth of the tops.

Confirmatory evidence is found in physiological studies on tuber formation. Rosa pointed out in a preliminary note (35) that tubers set only when the carbohydrate content of the tops exceeds a certain level. In other words, a higher carbohydrate content in the tops is required for tuber setting than for top growth. Similar studies by the writer (6) led to the conclusion that an increase in temperature above the optimum caused an increase in the rate of respiration without a corresponding increase in photosynthesis, which resulted in a decrease in carbohydrate content and a retardation of tuber growth. Here, as in Rosa's work, the deficit of carbohydrate affected tuber growth rather than growth of the tops. The inference from these studies is that high temperature is more detrimental during tuber growth than at any pre-tuber stage.

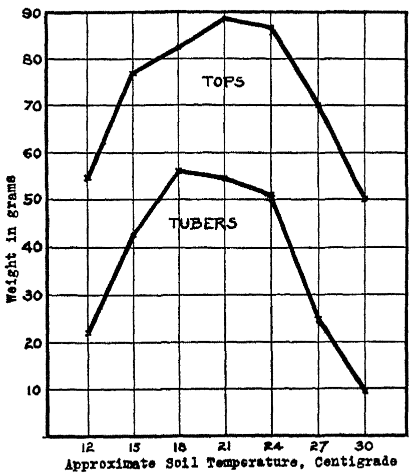


Fig. 1.—Effect of soil temperature on weight of potato tops and weight of tubers.
(Data of Jones, McKinney, and Fellows, 22)

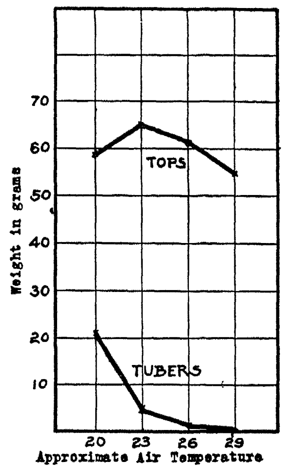


Fig. 2.—Effect of air temperature on weight of tops and weight of tubers.
(Data of Bushnell, 6)

Smith (37) attempted to determine more specifically the relative sensitivity at different stages of development by correlating the temperature at various calendar periods of the growing season with annual yields in central Ohio. He found a higher coefficient of correlation (the coefficient had a negative sign) between yield and July temperature than with the temperature of any other month. From this correlation he concluded that the crop of central Ohio is most sensitive to temperature during July, which he considered to be the month when tubers were setting. Consequently he concluded that the potato crop is most sensitive to temperature at the tuber-setting stage.

However, Smith's assumption that tuber setting occurs in July in central Ohio is open to question. At the present time early maturing varieties predominate in the vicinity of Columbus, and early varieties are at a late stage of tuber development in July. It might then be concluded that the crop is most sensitive to temperature at a late stage of tuber growth. But before accepting this conclusion a quite different interpretation of the data should be considered. Smith's correlation coefficients varied in numerical value directly with the normal temperature. This relationship indicates that the higher the normal temperature the more sensitive was the crop to variations above and below normal. For example, in seasons when June was a few degrees above normal, 70° F., there was less reduction in potato yields than when July was correspondingly above its normal of 74° F. By thus shifting the emphasis from the crop to the normal temperature, Smith's correlations become measures of the effects of temperature rather than measures of the sensitivity of the crop at different stages of development.

However, Smith's correlations for Portage County, in northeastern Ohio, do not fall strictly within this interpretation. In northeastern Ohio, as he pointed out, potatoes are commonly planted in June and do not tuberize until August. Consequently July temperatures do not have as much effect on yield as those of August. This is in agreement with the view expressed earlier, that the pre-tuber stages of growth are less sensitive to temperature than the tuber developing stage. When thus qualified, all of Smith's temperature correlations fall within the general conclusion that the higher the normal temperature during tuber development the more sensitive the crop becomes to variations from normal.

Similar correlations by Hooker (20) based on conditions of eastern England gave much lower correlation coefficients than those of Smith. In eastern England temperatures are lower than in Ohio, consequently departures from normal are less significant. Taken as a whole, the correlation studies show that the potato crop is sensitive to temperatures such as occur during the summer in Ohio, and indicate that tuber growth is more sensitive than the earlier stages of growth, but they do not prove that the tuber-setting stage is especially sensitive to temperature.

Altho the concept of peculiar sensitivity at time of tuber setting has not been established, the opinion has been occasionally advanced that the time of planting should be adjusted to avoid hot dry weather at tuber setting. Jones (21) and Clinton (11), prior to the publication of Smith's correlations, held this view, altho neither of them offered experimental data in support of it. More recently, Stuart (38), Moore (31), and Cormany (12), basing their statements in part on Smith's correlations and in part on their own observations, have emphasized the necessity of favorable weather at tuber setting.

It is entirely possible that this emphasis upon tuber setting as a critical stage may be due to the ease of observing tuberization. Any condition preventing tuber setting is readily detected by examination of the stolons. On the other hand, after tubers have started growth, any temporary retardation of growth is far more difficult to detect by mere observation. Consequently, inhibition of tuber setting has been more frequently noted than retardation of later stages of tuber growth.

After reviewing the evidence, the writer is not convinced that tuber setting is peculiarly sensitive to unfavorable weather. Certainly there is no adequate justification for basing planting practices upon this concept. Therefore, in the discussion that follows, the generalization made earlier remains unqualified: during the entire period of tuber development the plant is sensitive to the high summer temperatures, more sensitive during tuber development than during the earlier stages of growth.

Another effect of temperature that may have a bearing on the time of planting is a premature ripening which results in decreased yield. This phenomonon has been studied but little. Jones and co-workers (22), in reporting the soil temperature experiments mentioned above, stated that plants grown at higher temperatures matured earlier, but they gave no data. In some districts of the south the effect is evident in the field. For example, in Arizona, where the cool period of spring is very short, McClatchie (28) stated that, "The increasing heat and aridity of June hasten the maturity or death of all potato tops, regardless of when they were planted or what the variety may be". In a previous work (29) he showed that this was not due to drouth, for yields in experimental plots were low even with abundant irrigation.

In northern Ohio, the premature ripening, or acceleration of the growth cycle, may have some bearing on the date-of-planting problem but the effect is not conspicuous. The Rural varieties survive the heat of midsummer without apparent injury. In a quantitative sense, then, it is impossible to state whether or not this premature ripening is of importance to the problem at hand. For the present the phenomenon merely emphasizes the general importance of temperature.

Again, high temperature at the time of planting may be a serious factor. In hot soils an excessive rotting of the seed pieces has been observed. The rotting, which is evident when the seed pieces are examined after planting, is probably a secondary effect, following death caused by deficiency of oxygen. In the light of the studies on blackheart by Bennett and Bartholomew (3), who found partial death of tuber tissue after a week at 77° F. when the oxygen supply was restricted, it seems highly probable that a similar suffocation may take place in the field when the soil approaches this temperature. If this be the explanation, suffocation would be more likely to occur on heavy, poorly aerated soils than on sandy soils. This agrees with observations. On the other hand, suffocation is not a complete explanation, for in the writer's experience whole tubers have endured hot soils better than cut pieces. But whatever the explanation may be, the important point for the problem at hand is that soil temperature must be taken into consideration when planting is deferred until early summer.

To summarize, high summer temperatures in northern Ohio may produce three detrimental effects:

1. Rotting of the seed pieces.
2. Shortening of the vegetative cycle (still an open question)
3. Retardation of tuber growth.

From the temperature viewpoint, therefore, the ideal planting date insures a cool period of the season for tuber development and at the same time avoids hot soils at planting. Theoretically and practically this may be accomplished in northern Ohio by planting at a time that will insure tuber development during the cool weather of autumn. Such plantings may usually be made before the soil becomes hot or after it has been cooled by rain. The practical difficulty of determining the exact planting date which will place the tuber development in the cool of the autumn and at the same time insure a satisfactory degree of maturity at the time of killing frost, has been considered the most important phase of the present study.

**Rainfall.**—In spite of the emphasis that investigators have placed upon temperature as a limiting factor under Ohio conditions, there is a widespread popular opinion that drouth is a more important factor. This opinion is revealed in the statistics on the "cause of reduction from full yields" compiled by the U. S. Bureau of Agricultural Economics from figures received from numerous crop correspondents. The average reductions in yield for the 15 years, 1909 to 1923, inclusive, according to these reports were as follows (4):

| | |
|---|---|
| From deficient moisture | 13.4 percent |
| From excessive moisture | 3.1 percent |
| From hot winds | .7 percent |

In these statistics no category is given which might directly include the effect of high temperature other than "hot winds". Indirectly, of course, "deficient moisture" might include the effect of hot weather accompanying drouth, but there is no such implication in the figures as published.

Contrary to this view, the evidence from climatological and irrigation studies shows that the potato crop tolerates a wide range of moisture. In the eastern half of the United States according to Smith (37) the average rainfall during the growing season of the late crop varies from 8 to 22 inches. Smith found no apparent relation between average precipitation and yield per acre where the rainfall exceeded 10 inches for the growing period.

The capacity of the crop to endure low rainfall is more clearly demonstrated by its importance in the dry-farming region of the semi-arid west. Werner recently stated (44) that in western Nebraska, "good crops of potatoes can be produced in a region having an annual precipitation of 14 to 15 inches, if a minimum of 6 to 7 inches comes during the growing season, especially the middle or latter part".

Irrigation experiments show more quantitatively the effect of varying amounts of water. Harris and Pittman at Utah (19) applied water in measured quantities at weekly intervals. The averages of five years showed no great differences in yield over a range of 10 to 60 inches of total irrigation water. Powers and Johnston at Oregon (34), attempting to determine the minimum quantity of irrigation water required for optimum yields, found that on the average the crop required about 9 inches of water—that is, irrigation plus rainfall—when the irrigations were skillfully applied at the proper time. Many similar experiments designed to furnish a basis for empirical recommendations in the economical use of water are found in the literature reviewed by Harris and

Pittman (19). In this literature the emphasis is upon the necessity of frequent irrigations rather than upon the need of a large amount of water. The general conclusion may be drawn from the irrigation experiments that when the applications are made at proper intervals the total water requirement of the crop is not far from 10 inches.

On the other hand, when irrigations are applied at improper intervals, particularly if the plants are allowed to show definite signs of drouth at any time, the total water required for optimum yields is much greater. Harris and Pittman (19) found that a total of 20 inches of water applied alternate weeks was required to give the same results as a total of 10 inches applied weekly. Similar results have been reported by other investigators.

In the more humid eastern half of the United States where irrigation of potatoes is but rarely practiced, the normal rainfall during the growing season of the main crop is generally greater than ten inches but it is not always well distributed. The problem of insufficient rainfall as a limiting factor in Ohio is then a question of short periods of drouth rather than deficiency of total rainfall. From the date-of-planting viewpoint, the problem here, as in the case of temperature, may be integrated into a study (1) of the sensitivity of the plant to drouth at different stages of development and (2) the occurrence of drouth as shown by the weather records.

The sensitivity of the crop to deficit of water was studied by Harris (18) in an elaborate experiment in which irrigations were omitted at different stages of the plant's development. He found that the yields were most seriously reduced by omission of the late irrigations, showing that under Utah conditions, the crop is most sensitive to drouth during tuber growth. His conclusions are probably applicable to northern Ohio, for temperatures at Logan, Utah, are similar to those of Cleveland, and the experiments were carried out with Rural varieties similar to the standard varieties of northern Ohio.

On the other hand, irrigation experiments of King (25) at Wisconsin indicated that drouth in July is most serious. Compared to the work of Harris, King's experiments were very superficial. Moreover, King did not emphasize in his writings the fact that only in years with a drouth in July were irrigations beneficial. But a comparison of the results for the eight years of his experiments with the rainfall records as given by Whitson (47) shows that only in the four years characterized by a drouth in July, were the irrigations significantly beneficial. Similarily, correlations of weather and annual yields computed by Smith (37) from data of central Ohio, led to the same conclusions: July rainfall is more important in potato yields than rainfall of any other month. Thus under non-irrigation in Wisconsin and Ohio the crop appears to be most sensitive to drouth in July, while in the irrigation studies in Utah the crop was about equally sensitive thruout the entire tuber growing stage.

Probably the explanation for this discrepancy in the experimental figures lies not in a difference of the sensitivity of the crop under the different conditions of the experiments, but rather in the fact that the water requirement of the crop is higher during July than other months. Pot experiments at Wisconsin carried out by King (24), disclosed a transpiration curve with the peak in July; as a matter of fact, the transpiration curve had the same character as a temperature curve. This influence of temperature on transpiration was probably appreciated by Harris when planning his experiments and the time of application of water determined accordingly.

The variation in transpiration during the growing season gives the same character of curve as the evaporation from a free water surface, and a comparison of evaporation with rainfall in Ohio shows an interesting interrelation. At Wooster, during the summer months, the evaporation from a free water surface exceeds the rainfall and the peak of the evaporation is in July. The data of Figure 3, illustrating the divergence of the evaporation and rainfall curves, are from the Wooster records. As the greatest divergence is in July, it seems highly probable that the underlying reason for the importance of July drouth, reported by King and by Smith, lies in the ratio of evaporation to rainfall. It is in July that the average evaporation most exceeds the precipitation. Hence, it is in July that the plant is most likely to suffer from drouth.

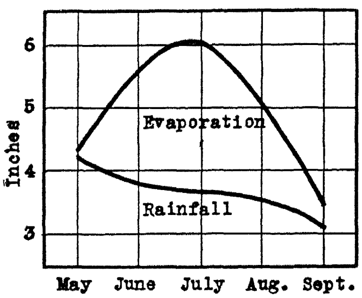


Fig. 3.—Evaporation and rainfall at Wooster, 1917 to 1925, showing the excess of evaporation during the summer

To summarize, the potato plant is probably most sensitive to drouth during the later stages of its vegetative cycle as shown by Harris, but under Ohio conditions the potato suffers from drouth only when accompanied by high evaporation. Evaporation in turn appears to be largely a function of temperature.

In its practical aspects, then, the problem of avoiding drouth is exactly the same as the problem of avoiding injurious temperature. The potato plant is most sensitive to both drouth and high temperature during the period of tuber development. However, since drouth is most detrimental when accompanied by high temperature, while high temperature is detrimental whether accompanied by drouth or not, the practical problem of avoiding unfavorable weather in Ohio is primarily a consideration of temperature.

## DATE-OF-PLANTING EXPERIMENTS AND PRACTICES

Numerous short-time field experiments on time-of-planting potatoes are reported in the literature. In order to select from these reports those that bear on the problem at hand, it is necessary to have in mind the extent of the region with a planting problem similar to that of northern Ohio. Planting practices thruout most of the United States and Canada are well established. The geographic extent of the region with a problem similar to that of Ohio may be readily shown by a brief survey of these current planting practices.

**Northern region.**—In the latitude of Maine, northern Michigan, North Dakota, and northward, a region characterized by a growing period of 140 days or less, the crop requires the entire season to mature. The practice, therefore, is to plant in the spring. In general, the longer the growing season, the larger the yields. The advantages of early planting in the north are illustrated in the experiments of Macoun at Ottawa (27), Weston in northern Michigan (46), Kohler in Minnesota (26), and Werner in North Dakota (43). The highest yields in all of these experiments were from early plantings.

In these northern regions the varieties are more or less adapted to the length of the season. Green Mountain and Rural types are standard where the growing seasons are long enough, but in Canada where seasons are shorter these are largely replaced by earlier-maturing varieties. The length of season largely determines the variety as well as the yield, and the date-of-planting problems are those involved in early planting.

**Southern districts.**—In southern Ohio and southward, summer temperatures are clearly too high for potatoes. They are therefore grown during the cooler weather of spring or fall. Stuart (38) has presented a comprehensive survey of the practices in the south, giving the planting dates as well as the varieties for each of the states in this region.

He pointed out that the spring crop is generally planted as soon as the soil is warm enough to insure germination. Early-maturing varieties are grown, and the crop harvested about 100 days after planting. Commercial production of the spring crop is largely localized in the coastal regions which are characterized by cool spring weather prolonged for at least three months.

The fall crop is planted at such a time that most of its growth is made during the cool weather of the fall months. As Stuart put it, "Planting is delayed as long as is possible and still be reasonably certain of a sufficiently long growing period to permit the tubers to reach a full size, or at least to make a fair crop". For the fall crop therefore, varieties requiring a long growing season are planted earlier than those requiring only a short season.

In the south the dates of planting are well established and the underlying principles generally appreciated. Since the potato can be grown only during the cool weather of spring or fall, planting practices have evolved accordingly.

**Intermediate zone.**—Between the northern short-season region and the southern hot-summer region lies an intermediate zone in which the growing season is longer than the late-maturing varieties require and where summer temperatures are not as clearly a controlling factor as in the south. Northern Ohio lies in this intermediate zone. Here the planting period is not sharply defined. The diversity in planting practices mentioned in the introduction is not restricted to Ohio, but extends to the east and to the west.

Thruout this zone the Rural varieties predominate. In Ohio, Rurals have been widely planted for many years and are generally recommended as the best of the late varieties. According to reports of agencies selling certified seed, the Russet Rural and White Rural are the only late-maturing varieties now being sold by them in the State. The importance of these varieties is further illustrated by the fact that Rural types alone have been accepted for certification during the six years of state inspection of seed potatoes in Ohio. Judging from the literature of the experiment stations the same is true in the states to the east and west. The time-of-planting problem in the intermediate zone is very largely one as to the best time to plant the Rural varieties.

The southern limit of the intermediate zone may be considered to be the line where the Rurals give way to the earlier-maturing varieties of the south. In Ohio this line is rather definite and follows roughly the isotherm of 74° F. July temperature in the western half of the State and 73° F. in the eastern half. (See July temperatures, Fig. 7). The reports of the agencies selling certified seed[1] show that the bulk of the Rurals shipped into Ohio are delivered to points north of these isotherms, while the Early Ohio and Irish Cobbler are the popular varieties to the south.

The fact that July isotherms so closely fit the southern limit of the Rurals, implies that summer temperature is the controlling factor in the variety distribution. However, as pointed out later in the discussion of climate, the character of the fall weather may also be involved. In southern Ohio, south of the intermediate zone, the spring weather appears to be more favorable for potatoes than the fall weather, whereas in northern Ohio the fall weather is the better. It is not surprising therefore that the spring crop of early-maturing varieties is the dominant crop at Columbus, while the fall-maturing crop is the dominant crop near Lake Erie. It is unnecessary to go into this question here; the significant point in the present connection is that the distribution of varieties has a climatological basis.

The northern limit of the intermediate zone, where the growing season is no longer than the crop requires, lies north of Ohio. It does not need to be accurately defined for the present discussion.

In the intermediate zone as a whole, field experiments on time-of-planting have usually shown highest yields from plantings made about the middle of May. Jones (21) while at Vermont maintained from limited data, that plantings after May 10 generally gave larger yields when adequately sprayed than earlier plantings. Cormany (12) recently published three-year averages of a date-of-planting experiment in central Michigan, in which the planting of May 14 gave the highest yield. Champlin and Winright (9) in South Dakota found plantings of May 15 gave higher yields in two consecutive years than earlier or later plantings. Zavitz (48) at Gueph, Ontario, in an experiment conducted for six years, secured higher yields from May 31 than from later plantings. In one season he planted earlier than May 31, and the earlier plantings produced the highest yields. At all of these points the May plantings probably remained green and growing thru most if not all of the cool fall period. Adopting the terminology of the south, they may therefore be classed as "fall" crops.

On the other hand, Erwin and Rudnick (13) at Ames, Iowa, found that early April plantings outyielded later plantings three years out of four. Ames has a mean July temperature of 74° F.

[1]Information received largely from C. W. Waid of the Ohio Farm Bureau Federation.

(similar to that of Columbus, Ohio) and is probably near the southern edge of the intermediate zone. Without giving details of the weather, Erwin and Rudnick interpreted their results as due to temperature. On the basis of their data they recommended early spring planting of Rurals for Iowa.

These field experiments are in essential agreement with current farm practices, as far as the practices in this zone can be determined from the meager statements in the literature. The bulk of the fall crop appears to be planted somewhat later than the experiments indicate would be the best date, perhaps due to the fact that under experimental conditions of good culture and thoro spraying, plants remain alive longer than under practical farm treatment. For instance, in the southern peninsula of Michigan, according to Moore (31), planting begins late in May and extends into June. In northern and western New York, Hardenburg (17) in a farm practice survey found the average date of planting to be the last ten days of May. In Steuben County, in southern New York, a similar survey by Fox (13a) showed that two-thirds of the farmers planted the latter half of May. In northeastern Ohio, where the climate is modified by Lake Erie and the potato is of considerable importance as a farm crop, planting is commonly deferred until June (Glines 14). In Iowa, Erwin and Rudnick (13) were of the opinion, at the time they wrote, that the majority of growers planted potatoes after corn planting, probably late in May.

On the other hand, along the southern edge of the intermediate zone, early planting appears to be more common, agreeing with the experiments of Erwin and Rudnick. As they point out, some growers in Iowa plant their main-season varieties (Rurals) at the same time as early potatoes. In Ohio the writer has observed that early April planting is common in the vicinity of Wooster, Wayne County, and to the west in Richland and Auglaize Counties. Hardenburg (17) reports April 9 as the average planting date on Long Island, N. Y. Parenthetically it should be added that the Green Mountain variety is more popular on Long Island than the Rurals, but this probably has no effect on the time of planting. Taking the situation as a whole, early planting of main-crop varieties as a commercial practice in the intermediate belt is confined to a relatively narrow strip along the southern edge of the zone.

As central Ohio lies along the southern edge of the intermediate zone, it might be expected that a belt of early planting would extend across the State. Actually, early planting is as yet restricted to a relatively few localities.

In concluding this review of planting experiments and planting practices in the intermediate zone, one point requires re-emphasis: the discrepancy between experimental results which point to the middle of May as the best time to plant, and the practice of delaying planting until June. This discrepancy between experimental results and common practice has undoubtedly been one of the chief obstacles in arriving at consistent recommendations.

## EXPERIMENTAL DATA

Field experiments on time of planting have been conducted at Wooster for six seasons. As would be expected from an experiment in which the results are largely a function of weather, the data do not appear to be entirely consistent. However, in the light of the evidence just reviewed and the analysis of climate that follows, much of the inconsistency may be explained.

**Yields.**—In an experiment conducted by J. H. Gourley in 1910 (results not previously published), the planting of May 15 gave the highest yield (Table 1). The earlier plantings gave but slightly lower yields while the June plantings were decidedly lower. The low yield of the June plantings was not entirely due to immaturity but was partly due to weak plants resulting from loss of vigor in the seed held in an ordinary cellar storage. Seed that was greened (sun-sprouted) and planted as late as July 2 yielded 387 pounds or very nearly the same as the early plantings.

**TABLE 1.—Yield of Potatoes From Different Plantings, 1910**

Pounds per plot. Carman No. 3, a Rural type

| Planted | Total yield | Percent small |
|---|---|---|
| April 15 | 384 | 17 |
| May 1 | 400 | 13 |
| May 15 | 404 | 13 |
| June 1 | 313 | 15 |
| June 15 | 280 | 14 |

In 1917 Green (15) published the results of a similar experiment, probably conducted during 1916, in which plantings were made at weekly intervals from May 10 to June 30. His planting of May 17 gave the highest yield. He also emphasized the necessity of giving particular attention both to the storage of the seed during the spring months and to the good results from greening.

In 1922, under the direction of J. B. Keil, the problem was again taken up and the study has been continued to date. At that time a special plot of land five times as large as the annual requirement was set aside for the experiment so that only one-fifth need be used each year. The plot had not been planted to potatoes for many years and as a new section has been used each season, the crop has not been planted on soil that has recently produced potatoes. This precaution is emphasized because in short rotations at Wooster serious difficulties have been encountered from *Fusaria* and other pathogens surviving in the soil.

The soil is Wooster silt loam and was in heavy sod in 1922. Each spring the area to be used has been plowed not long before the first planting, except in 1925 when the sod was broken the previous year and a crop of soybeans plowed under in the fall. A fertilizer mixture approximating a 3-12-7 has been broadcasted on the experimental area each year at the rate of 500 pounds per acre prior to the first planting. No manure nor lime has been applied. The soil is distinctly acid in reaction. Colorimetric hydrogen-ion determinations in the fall of 1925 showed a pH of about 4.8.[2]

The Russet Rural, the variety most widely grown in northern Ohio, was selected for the experiment. However, the selection of a representative strain has been complicated by the variation existing within this variety. During recent years the earlier-maturing types have been gaining in popularity, until today they may be said to be the standard Russet Rural. But prior to 1924 this fact was not realized, and a late-maturing strain, described elsewhere, (Bushnell 8), was planted in 1923 and 1924. The results from these two years are therefore of little practical significance in determining the best date of planting the earlier-maturing Rurals, altho they are applicable to the larger problem involving the underlying generalizations.

Certified seed was purchased each year, stored in a barn basement until the tubers showed signs of sprouting, when the entire supply of seed was spread on trays and moved to an open shelter to green.

In planting, cultivating, spraying, and harvesting an effort has been made to follow good farm practice, except where hand work has been deemed advisable in order to insure experimental accuracy. The seed has been cut into pieces weighing about 1½ ounces and planted 15 inches apart in rows 3 feet apart. Whenever possible, the soil has been harrowed prior to each planting. Frequently, however, the soil has been too wet, and under such circumstances, plantings have been made at the predetermined date without waiting for favorable conditions. The plantings made in wet soil have developed satisfactorily and as far as the data show, there has been

[2]Hydrogen-ion determinations made by L. D. Baver in the Soil Survey laboratories.

no appreciable error introduced by the differences in the condition of the soil at time of planting. No serious injury has occurred at any time from insects or diseases. Apparently the yields as recorded were largely due to the response of the different plantings to weather conditions.

In spite of the evidence from the earlier data, Keil assumed that the middle of June was the best time to plant and consequently decided to compare earlier and later plantings with those made the middle of June.

Under his direction, plots made up of five adjacent rows of 50 hills each were planted at intervals of about ten days in 1922 and 1923. The yields for the two years and the percentages of culls calculated as bushels per acre are summarized in Table 2.

**TABLE 2.—Yield of Potatoes From Different Plantings, 1922 and 1923**

Bushels per acre

| 1922 | | | 1923 | | |
|---|---|---|---|---|---|
| Planted | Yield | Percent small | Planted | Yield | Percent small |
| May 24........... | 102 | 15 | May 22... ..... | 244 | 7 |
| June 2.......... | 117 | 12 | June 1.......... | 221 | 6 |
| June 13........... | 99 | 11 | June 13 . ...... | 196 | 11 |
| June 24 .......... | 75 | 18 | June 22 ........ | 189 | 11 |
| July 7.... ....... | 48 | 36 | July 2.... . ... | 155 | 17 |

This table shows that in both years the earlier plantings outyielded the later plantings. The two seasons' data do not agree as to the exact date giving the highest yield. The discrepancy is doubtless due to the fact that the strain used in 1923 was later maturing and therefore required earlier planting in order to secure the most advantage from the favorable fall weather. It is also possible that a severe drouth occurring during August and September, 1922, reducing the yields of all plantings, may have favored the June planting. But as a whole the figures of these two years agree with those of Gourley and of Green in that plantings after the second day of June yielded less than late May plantings. However, in the four seasons, the actual date giving the highest yield varied from May 15 in 1910 to June 2 in 1922. Moreover, the important question of the value of April planting was only considered in one season, 1910.

In 1924 the problem was taken over by the writer, who changed the plan to include check plots as well as early plantings. This necessitated reducing the size of plots to three adjacent rows instead of five, leaving space for check plots of two rows. The late-maturing strain used in 1923 was again planted.

The 1924 season was unusually favorable for potatoes. The combination of favorable weather and a late-maturing variety resulted in excellent yields of the early plantings. The planting of May 6 remained green until frost, October 23, producing a yield equivalent to 290 bushels per acre. Later plantings, being immature at frost, yielded less, as shown in Table 3. The earliest planting yellowed somewhat before frost and evidently failed to secure as much advantage from the late fall as the planting of May 6. However, when the yields were corrected by comparison with the checks, this planting outyielded the April planting by only 4 bushels per acre—an insignificant difference.

**TABLE 3.—Yield of Potatoes From Different Plantings, 1924**

Bushels per acre

| Planted | Actual yield | Yield of checks | Increase over checks | Corrected* yield | Percent small |
|---|---|---|---|---|---|
| | | 244 | | | |
| April 25 | 286 | | 47 | 290 | 13 |
| | | 234 | | | |
| May 6 | 293 | | 51 | 294 | 6 |
| | | 250 | | | |
| May 17 | 288 | | 34 | 277 | 6 |
| | | 258 | | | |
| May 30 | 257 | | 21 | 264 | 8 |
| | | 214 | | | |
| June 17 | 208 | | —22 | 221 | 9 |
| | | 247 | | | |
| June 30 | 163 | | —86 | 157 | 14 |
| | | 251 | | | |
| July 8 | 126 | | —121 | 122 | 12 |
| | | 244 | | | |
| June 7 | Checks | 243 | | 243 | 8 |

*Corrected for plot variation by adding the increase over the mean of adjacent check plots to the average of the checks.

The season's results illustrate the advantage of a late-maturing strain planted early in a favorable season. As yet, however, the late strains of Rurals are not recommended for northern Ohio. In variety tests, the late strains have been inferior in quality to the standard earlier Rurals. Moreover, the early-maturing strains are rapidly becoming the standard varieties in the states to the north, from which Ohio growers secure the bulk of their certified seed. The practical planting problem at present is therefore chiefly concerned with the popular early type of Rural.

In 1925, the early-maturing type was adopted. The planting plan was again altered in order to increase accuracy by the use of replicates. As no competition between adjacent rows has been detected in field technic studies at Wooster, single row plots were adopted, replicated eight times, and the check rows were omitted.

Abnormally high temperatures occurred in June. The mean for the month was 4.3° F. above normal. In an experimental plot of winter wheat, soil temperatures at a depth of one inch averaged 75° F. for each of the first three weeks of the month.[3] Due to the hot soil, the stand of the June plantings was seriously reduced by rotting of the seed pieces. Many of the plants that did appear in these plantings were weak, similar in character to plants from very small seed pieces, a result undoubtedly due to partial rotting of the sets. The planting of May 28 was also somewhat injured by the unfavorable conditions in early June, as shown by a reduced stand, but not as much as the plantings made directly in the hot soil.

The highest yield, Table 4, was from the planting of May 13. As in 1910, the April plantings fell below the planting of the middle of May by a few bushels per acre.

**TABLE 4.—Yield of Potatoes From Different Plantings, 1925**

| Plot | April 13 | April 28 | May 13 | May 28 | June 13 | June 30 |
|---|---|---|---|---|---|---|
| | Total yield for each replicate, bushels per acre | | | | | |
| A | 254 | 273 | 273 | 240 | 90 | 70 |
| B | 273 | 284 | 270 | 261 | 124 | 61 |
| C | 282 | 283 | 271 | 239 | 144 | 106 |
| D | 254 | 251 | 241 | 231 | 106 | 73 |
| E | 263 | 240 | 260 | 230 | 74 | 45 |
| F | 193 | 233 | 263 | 237 | 118 | 78 |
| G | 257 | 244 | 254 | 221 | 117 | 102 |
| H | 266 | 229 | 258 | 220 | 96 | 98 |
| I | 227 | 231 | 251 | 218 | 93 | 131 |
| Av. | 252 | 252 | 260 | 233 | 107 | 85 |
| | Percent small | | | | | |
| | 3.4 | 4.2 | 3.7 | 2.2 | 3.3 | .0 |
| | Yield where stand was perfect | | | | | |
| | 253 | 253 | 260 | 249 | 189 | 113 |

In the face of the current practice of delaying planting until late May or June, the question might be raised: If the planting of May 28 had had a normal stand would it not have outyielded that of May 13?

A partial answer to this question is given at the bottom of Table 4 in the yield from those parts of the plot having perfect stands. At harvest, particular attention was given to errors introduced by the reduced stand. The hills adjacent to missing hills were first dug by hand, counted, and weighed, then the hills in a normal position between the hills were likewise counted and weighed. The last line of Table 4 includes only the weight of the

[3]From thermograph records secured by F. A. Welton.

normal hills. On this basis, the planting of May 13 outyielded that of May 28 by about 9 bushels per acre. Calculated from the original records by Student's method, the odds are 41 to 1 that this difference is not due to chance.

However, killing frost this year was six days earlier than the average date, a fact favoring the earlier planting. In October prior to frost, frequent observations were made on the maturity of the different plantings as judged by the yellowing of the foliage. About 95 percent of the foliage on the planting of May 13 was yellow or dead at the time of frost. This planting was evidently near the end of its vegetative cycle. On the planting of May 28, 40 percent of the foliage retained a normal green color. If frost had held off until October 16, the average date at Wooster, there is little doubt that this greener planting would have continued to increase in tuber weight and might have overtaken the earlier planting in yield.

It cannot therefore be concluded from these data that under average conditions plantings made May 13 would be significantly higher or lower in yield than plantings later in May.

An interesting method of determining more exactly the best date of planting is by calculation from the figures on length of growing period.

Arbitrarily selecting as the close of the growing season the date when 90 percent of the foliage is yellowed or dead, observations in 1925 showed that the May planting had a growing period of about 145 days, Table 5. Earlier plantings, being slower to germinate, required longer to mature. As a basis for calculating the date of a planting which would mature coincidentally with frost, 145 days probably approximates the average growing period of May plantings. With the killing frost for potatoes occurring October 10, as in 1925, a planting of May 18 would theoretically have matured at the time of frost, and consequently have given the highest yield. This type of calculation has further possibilities in deriving generalizations as will be shown later.

**TABLE 5.—Length of Growing Period of Different Plantings, 1925**

| Planted | Date 90 pct. dead* | Growing period, days |
|---|---|---|
| April 13 | Sept. 20 | 156 |
| April 28 | Sept. 25 | 151 |
| May 13 | Oct. 5 | 145 |
| May 28 | After Oct. 10 | More than 135 |

*End of growing season estimated as the date when 90 percent of foliage was yellowed or dead.

In summarizing the results from the six years, five points stand out:

1. Plantings maturing coincidentally with killing frost gave the highest yields.

2. The highest yields, except for the two seasons when a late-maturing strain was grown, fell within a planting period of 20 days:

1910, May 15
1917, May 17
1922, June 2
1925, May 13 (theoretically May 18)

3. The low yields from later plantings were due to one or more of three causes: (a) immaturity at time of frost; (b) low vitality of seed from prolonged storage; or (c) reduced stand from planting in hot soil.

4. In the three years that plantings were made in April, the early plantings were consistently lower in yield than the best May plantings, but the differences were small.

5. The results are in essential agreement with experiments conducted elsewhere in the intermediate zone.

**Tuber characters.**—So far, attention has been focussed entirely on the yield phases of the date-of-planting problem. However, in the literature bearing on the problem, there are occasional references to abnormalities of the tubers caused by unfavorable weather. It is generally known that certain varieties of potatoes, particularly the Early Ohio, produce irregular secondary growths when normal development is interrupted by unfavorable temperature. (See, for instance, Rosa, 36). Stuart (38) presented illustrations of four varieties with abnormal elongation of the tubers, which defects he attributed to the influence of hot dry weather.

The Russet Rural is one of the varieties most tolerant of unfavorable weather. This tolerance is one reason for its popularity in the intermediate zone. However, Cormany (12), who conducted a date-of-planting experiment with Russet Rural in central Michigan, reported that May plantings produced a high proportion of oversize tubers, some showing an internal discoloration. Both defects he attributed to hot dry weather at the time of tuber setting. Because of the low quality of the May plantings, Cormany recommended deferring planting until June, even tho in his experiments the best yield from June planting was 130 bushels per acre below that of the best May planting.

No such defects in tuber quality have been observed in the Wooster experiments. In 1925 when unfavorable temperature in June inhibited tuber setting in the early plantings until July, the quality of the tubers was not appreciably affected. Likewise, the quality of the June plantings, was not affected by the August drouth encountered at tuber setting. The June planted plots were immature at harvest, but were otherwise normal. As a matter of fact, all of the 1925 plantings would be classed as excellent table stock. Representative samples from three plantings are shown in Figure 4. The percentage of tubers weighing over one pound is given in Table 6. Neither oversize tubers nor abnormalities of any sort were a serious consideration in 1925.

**TABLE 6.—Oversize Tubers Produced in Different Plantings, 1924 and 1925**

Total weight of tubers weighing over one pound each, expressed as percentage of total yield

| 1924 | | 1925 | |
|---|---|---|---|
| Planted | Percent oversize | Planted | Percent oversize |
| April 25 | 1.0 | April 13 | 2.8 |
| May 6 | 9.3 | April 28 | 3.0 |
| May 17 | 6.7 | May 13 | 2.7 |
| May 30 | 10.4 | May 28 | 4.8 |
| June 7 | 10.3 | June 13 | 2.2 |
| June 17 | 9.0 | June 30 | 0.0 |
| June 30 | 0.0 | | |

On the other hand, the late-maturing strain grown in 1923 and 1924 produced a larger percentage of oversize, coarse tubers in most of the plantings that matured. This can not all be attributed to weather, however, for this strain has consistently produced oversized tubers in variety tests, while the earlier Rurals have with equal consistency produced desirable-sized tubers.

In this connection, it should be pointed out that variety studies on the standard Rurals have been in progress at Wooster for but four seasons, and only in 1925 were they used in the date-of-planting experiment. The limited observations at hand do not preclude the possibility of abnormalities in the future. Whenever the set is reduced from any cause and good growing conditions follow, over sized tubers may be anticipated.

That soil moisture has an effect on the setting of tubers has been shown in several irrigation experiments. (See, for instance, Harris and Pittman 19, or Clark 10). The writer (Bushnell, 5) found that nitrogen fertilizers also affected setting. It might be expected, therefore, that weather conditions leading to either a deficiency of moisture or of available nitrogen at the time of tuber setting would reduce the number of tubers, which would then be oversized if favorable weather followed.

Before leaving this phase, it might be added that the problem of oversized tubers involves the spacing of the hills and the number of plants per hill as well as the factors affecting setting. In Cormany's experiments, where May plantings produced an abnormal percentage of large tubers, the hills were spaced 18 inches apart. Moore (32) at the same station, studying hollowheart, recently reported that spacing affects the proportion of oversized tubers. The effect of closer spacing might be attained by the use of larger seed pieces giving a larger number of plants per hill. (See results of Stuart and co-workers, 39). Furthermore, there is some evidence (Bushnell, 7) that seed tubers will produce more sprouts when planted late than when planted early.

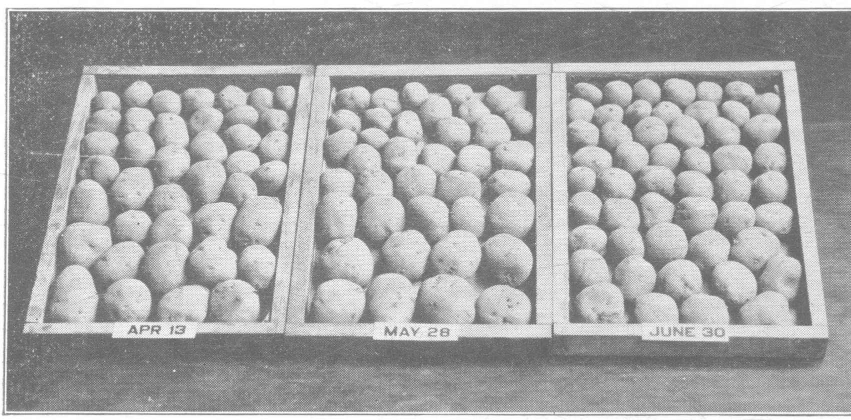


**Fig. 4.—Samples of tubers from different plantings, 1925**

The stand of plants and setting of tubers are phases of the problem that have not yet been given the attention they merit. In ordinary experimental procedure, a standard spacing has been adopted for all plantings in the studies reported in the literature. The results are, therefore, complicated by the variation in stand. With the spacing uniform the variation in number of plants per hill in the different plantings, arising from the change in character of sprouting, may have as much influence on yield and tuber quality as the weather. Altho it might be considered that the changes taking place in the seed tubers prior to planting and the resulting varia tions in stand are directly due to the date-of-planting, it might also be maintained that the cutting and spacing of the seed should be adapted to the condition of the seed so as to give the optimum stand and spacing for each planting. Correction for the change in sprouting habit has not been attempted in date-of-planting experiments, for the obvious reason that no adequate basis is available for determining the proper method of cutting and spacing to give ideal conditions. The final interpretation of field experiments, therefore, must be reserved until these aspects of the problem have been given some attention.

Since the interpretation of the field data is complicated by variation in the sprouting habit of the seed and the different spacing requirements of different plantings, it seems to the writer that the most promising procedure in clarifying the problem at this time is to focus attention upon the weather aspects. Weather records are taken at many points and cover a much longer period of years than do the date-of-planting experiments. In the light of our knowledge of the weather requirements of the potato plant, even tho this knowledge is not all that it might be, a study of the climate itself offers a valuable approach to the problem.

## CLIMATE OF NORTHERN OHIO AND TIME OF PLANTING

A comprehensive summary of the weather records of Ohio was recently published by Alexander (1). This summary includes the monthly means of both rainfall and temperature for all the years of record at the numerous cooperative weather bureau stations as well as regular weather bureau points. The maps derived from these data are peculiarly valuable to a study of the problem at hand. In addition to these data, the calculated normal daily temperatures for the regular weather bureau stations were recently published by Marvin and Day (30).

*Length of the growing season.*—One of the first considerations in the relation of climate to date-of-planting, that of the length of the growing period, cannot be determined directly from the published climatic summaries. The potato plant may endure frosts that kill more tender species—frosts that are recorded by the weather observers as "killing frosts". Consequently the season during which potatoes may be grown is longer than the "length of the frost-free season" reported by the weather bureau.

As a matter of fact, in the spring, potatoes may be planted as soon as the soil is warm enough to insure germination, almost without regard to the occurrence of late spring frosts. According to statistics of the U. S. Bureau of Crop Estimates (Baker, Brooks, and Hainsworth, 2), planting in northern Ohio begins on the average between April 1 and 21, about a month earlier than the average date of last killing frost. From a comparison of these planting statistics with weather records, Kincer (23) came to the conclusion that early potatoes are usually planted about the time the normal air temperature reaches 45° F. Alexander's map of the advent of spring (Fig. 5), based upon normal temperatures of 44° F. thus nearly coincides with the beginning of the growing season for the potato crop.

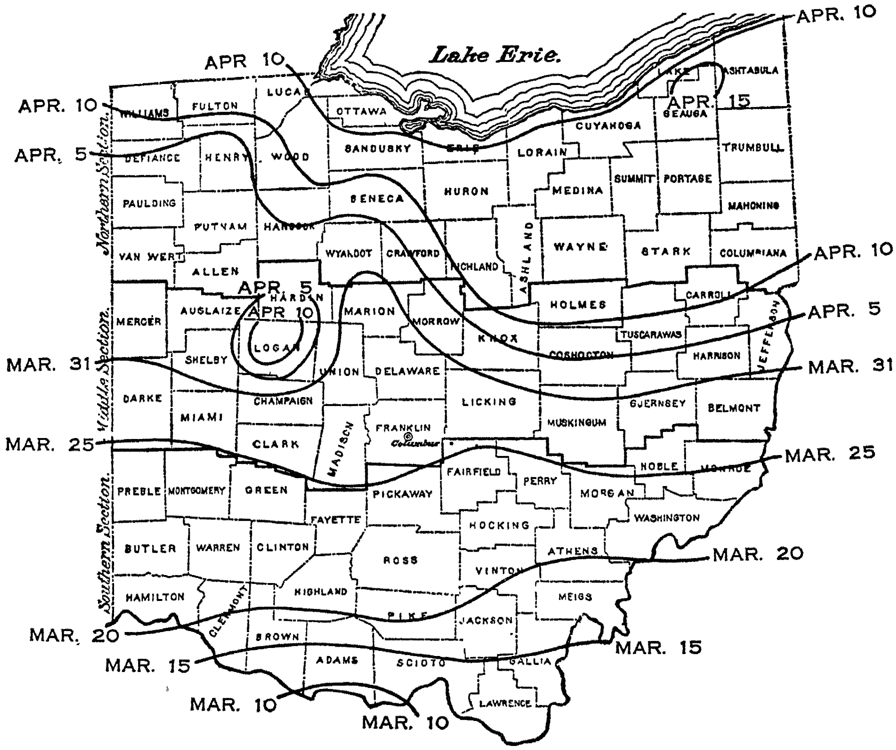


**Fig. 5.—Average Dates of Earliest Planting of Potatoes.***
**Based upon the date that normal temperatures reach 44° F.**

The end of the growing season is more difficult to determine. Neither statistics nor experimental figures on the temperature required to freeze potato tops have been found in the literature. At Wooster in 1924 potatoes were observed to endure a frost of 30° F., October 21, and to succumb a few days later to a temperature of 28° F. In the absence of experimental data, it may therefore be tentatively assumed that 28° F. or lower marks the end of the

*Figures 5-9 are from A Climatological History of Ohio by W. H. Alexander.

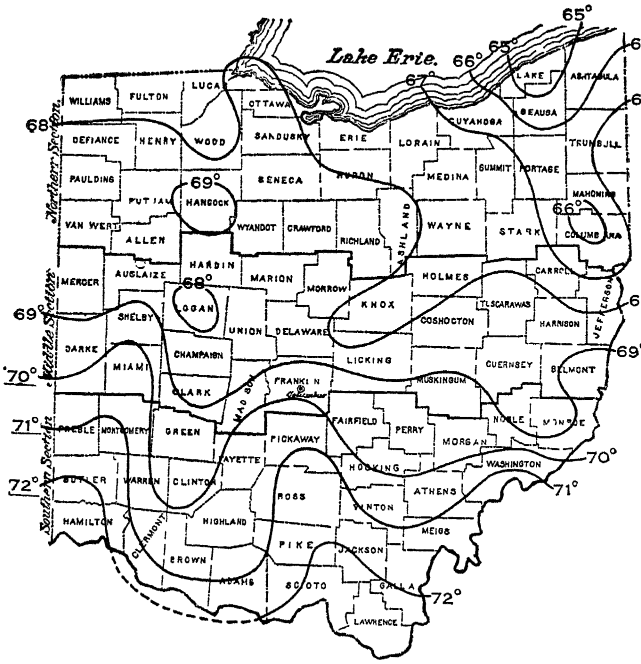


Fig. 6.—Normal Temperature Distribution in June

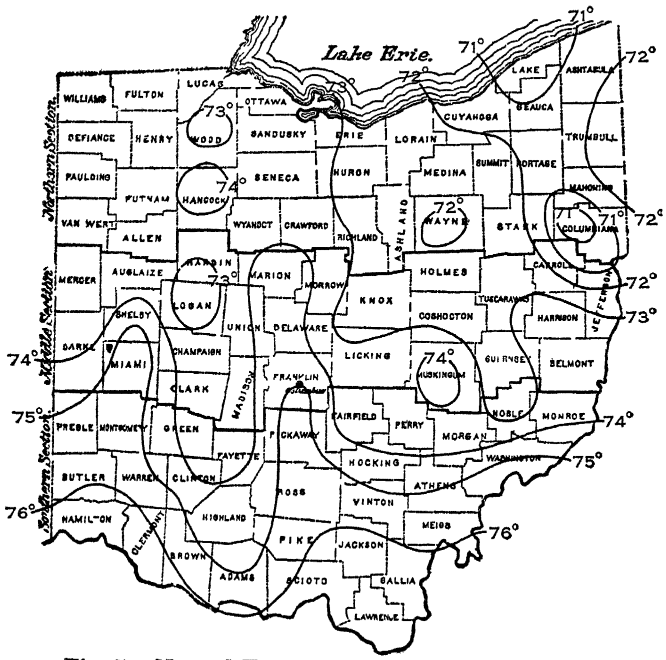


Fig. 7.—Normal Temperature Distribution in July

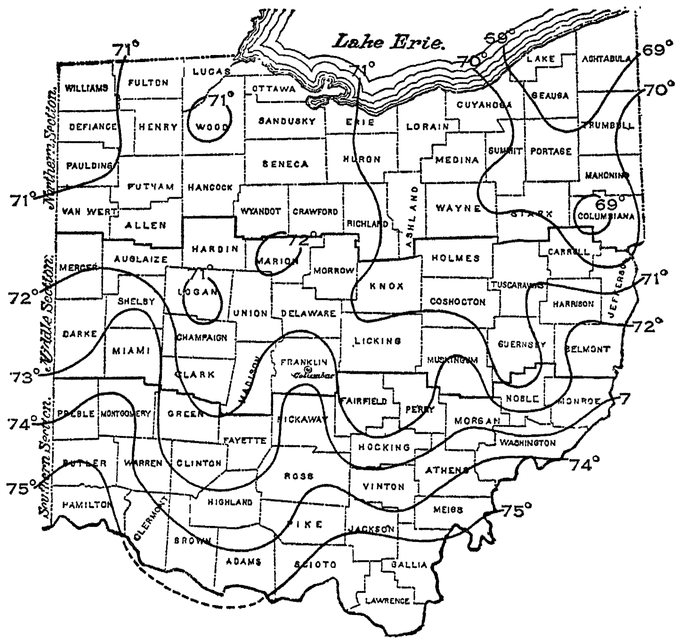


**Fig. 8.—Normal Temperature Distribution in August**

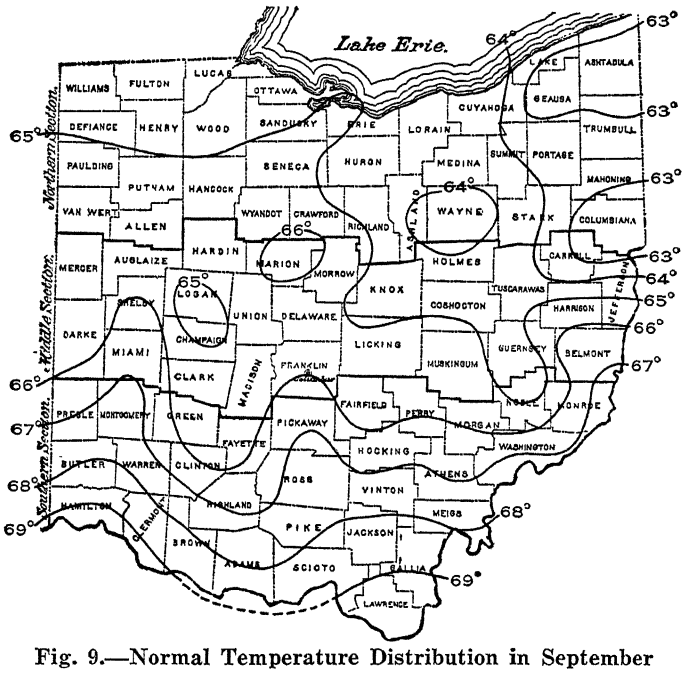


**Fig. 9.—Normal Temperature Distribution in September**

growing season. On this assumption the average date of killing temperature at Wooster is October 16, as shown in Table 8, nine days later than the date of killing frost recorded by the weather observer.

If the situation at Wooster is typical of northern Ohio, the average length of the growing season at other points may also be considered to extend about nine days beyond the isochrons of Figure 11, page 377. On this basis frosts severe enough to kill potatoes occur thruout most of northern Ohio, on the average, sometime after the middle of October.

As a whole, then, the growing season extends from the first half of April to the latter half of October, or nearly 200 days.

*Periods of weather favorable for tuber growth.*—In attempting to fit the vegetative cycle of the potato to the most favorable weather. it may be advisable to restate the essential requirements of the crop:

1. The dominant varieties of northern Ohio, the Russet Rural and White Rural, have a normal growing period at Wooster of 145 to 155 days.

2. The most important factor of weather, under Ohio conditions, is temperature.

(*a*) The optimum mean temperature for potato production is near 64° F.

(*b*) Favorable temperature is most essential during the period of tuber growth.

(*c*) High temperature at the time of planting may induce an excessive rotting of the seed piece.

From a casual examination of either the weather maps (Figs. 6, 7, 8, 9) or the normal temperatures (Fig. 10) it is evident that mean temperatures during July and August are too warm for successful potato production. Only during the spring and fall is the mean temperature near the optimum for tuber development. Rapid tuber growth and high yields are obtained only when the date of planting places tuber development in the favorable weather of either spring or fall.

From a more critical examination of the curves of Figure 10, it becomes further evident that late-maturing varieties, like the Rural group, cannot take complete advantage of the spring weather. In Figure 10 the normal temperature curves of both Columbus and Cleveland intersect the optimum for tuber growth (64° F.) within 50 days of the date of earliest planting (the intersection of 45° F.). Late maturing varieties, being slow to tuberize, require more than these 50 days for the pre-tuber stages of growth. Therefore tuber development in the earliest spring plantings would not begin until normal temperatures had passed above the optimum. The Rural varieties are not adapted to the spring weather.

When Rural varieties are planted early, as they are in a few localities in northern Ohio, they make use of the favorable weather occurring intermittently during the summer, rather than relying upon the cool weather of spring.

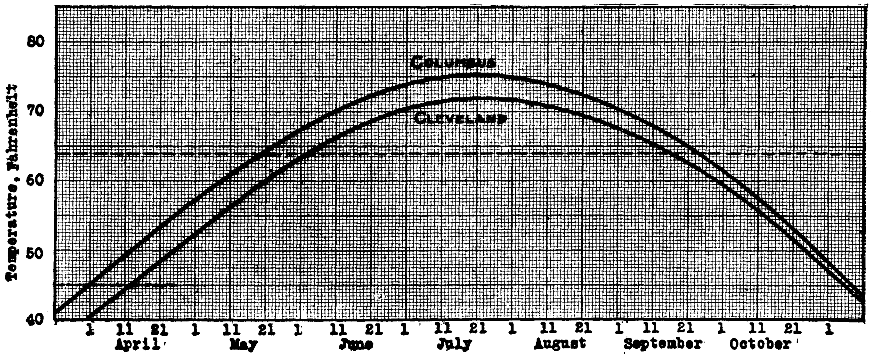


**Fig. 10.—Normal temperatures at Columbus and Cleveland.**
(Data of Marvin and Day, 30).
——— 64° F., approximate optimum for potatoes.
------- 45° F., approximate temperature of earliest planting.

Aside from the fact that the Rurals tuberize too late to take advantage of the spring weather, it may also be noted from the slope of the Cleveland temperature curve of Figure 10 at the intersections with 64° F., that there is a longer period of favorable temperature in the fall than in the spring. Doubtless this is one reason why the fall crop predominates over the spring crop in the vicinity of Cleveland and in general thruout northern Ohio. The difference in the relative length of spring and fall is further illustrated by a comparison of the number of days included between 59° and 69° F. normal temperature, a range 5 degrees either side of the optimum, as shown in Table 7. At Cleveland the period within this range of temperature is five days longer in the fall than in the spring.

**TABLE 7.—Periods With Normal Temperature Between 59° and 69° F.**
From data of Marvin and Day (30)

| | Spring | Fall |
|---|---|---|
| At Columbus.................... | May 6 to June 7, 32 days | Sept. 7 to Oct. 7, 30 days |
| At Cleveland...... ............ | May 19 to June 23, 35 days | Aug. 24 to Oct. 2, 40 days |

At Columbus, on the other hand, the spring period of cool weather is as long as that of the fall. Columbus is just south of the Rural zone. Near Columbus earlier-tuberizing, earlier-maturing varieties, adapted to the spring weather, predominate over the later-maturing varieties.

As far as the Rural varieties are concerned, the date-of-planting problem is then a question of making the best use of the fall weather. For convenience, such plantings have been, and will continue to be, referred to here as the "fall crop".

### TIME OF PLANTING THE FALL CROP

The selection of the best date for planting the fall crop has three aspects: (1) securing the largest possible amount of favorable weather during tuber development; (2) avoiding hot soils at the time of planting; (3) insuring marketably mature tubers in seasons of early frost.

From a consideration of normal temperatures alone (Fig. 10) it is a simple matter to solve the first phase of the problem, that is, to include all of the favorable weather of fall within the period of tuber development. Tuber development in the Rurals proceeds for about 90 days; the favorable weather is much shorter—not more than 60 days. Therefore, considering only the average or "normal" climate, plantings made at any time so that tuberization would take place between July 15 and August 15 would include all of the favorable weather within their period of tuber growth.

*Variation in fall weather.*—Dealing with the daily and annual fluctuations in temperature, the problem of successfully adapting the growing period to the weather is much more complex. Favorable weather does not occur at a definite predictable time, as in the normal temperature curve. Rather, favorable weather occurs intermittently; infrequently during the summer, more frequently in September and early October, and less frequently late in the fall.

The variation from month to month and from year to year is well illustrated by the Wooster records, summarized in Table 8. In this table the weather has been classified according to the number of cool days. As no adequate basis is at hand for accurately distinguishing between "favorable" and "unfavorable" potato weather, days with a maximum temperature below 80° F. were arbitrarily classed as "cool", and such days are undoubtedly more favorable for potato production than warmer days. The compilation thus gives a rough picture of the variation in favorable weather at Wooster during the past 32 years.

Confronted with the variation shown by this tabulation, the difficulty of selecting a planting date which will include the largest possible number of cool days during tuber development is apparent. The difficulty may be concretely illustrated by calculating the number of cool days during tuber development each year from different planting dates, as in Table 9. For this illustration, it was assumed that all plantings required five months to mature, and that tuber development proceeded during the last three months—an approximation based upon observations at Wooster.

**TABLE 8.—Number of Days With Maximum Temperature Below 80° F. for Each Semimonthly Period From June 1 to Killing Frost in Autumn at Wooster 1894 to 1925**

| Year | June | July | | August | | September | | October | | Frost* |
|---|---|---|---|---|---|---|---|---|---|---|
| | 16—30 | 1—15 | 16—31 | 1—15 | 16—31 | 1—15 | 16—30 | 1—15 | 16—30 | |
| 1894 | 1 | 5 | 2 | 2 | 3 | 3 | 13 | 14 | 2 | October 18 |
| 1895 | 4 | 7 | 6 | 1 | 4 | 7 | 9 | 8 | ........ | October 10 |
| 1896 | 8 | 4 | 9 | 2 | 15 | 9 | 15 | 15 | 6 | October 22 |
| 1897 | 8 | 3 | 6 | 5 | 14 | 3 | 5 | ........ | ........ | September 21 |
| 1898 | 6 | 3 | 1 | 6 | 6 | 8 | 9 | 12 | 12 | October 28 |
| 1899 | 7 | 5 | 3 | 6 | 0 | 9 | 12 | ........ | ........ | October 1 |
| 1900 | 5 | 4 | 4 | 2 | 0 | 2 | 13 | 10 | 16 | November 4 |
| 1901 | 3 | 2 | 0 | 5 | 2 | 8 | 14 | 4 | ........ | October 5 |
| 1902 | 12 | 3 | 3 | 9 | 6 | 12 | 10 | 15 | 15 | October 31 |
| 1903 | 13 | 3 | 5 | 8 | 6 | 5 | 11 | 15 | 9 | October 25 |
| 1904 | 7 | 7 | 6 | 5 | 8 | 8 | 11 | 14 | ........ | October 16 |
| 1905 | 5 | 0 | 6 | 5 | 8 | 13 | 8 | 14 | 7 | October 23 |
| 1906 | 8 | 3 | 4 | 0 | 2 | 5 | 9 | 10 | ........ | October 11 |
| 1907 | 5 | 5 | 3 | 4 | 9 | 9 | 11 | 6 | ........ | October 9 |
| 1908 | 4 | 2 | 3 | 4 | 7 | 3 | 3 | ........ | ........ | September 30 |
| 1909 | 3 | 3 | 6 | 3 | 7 | 10 | 11 | 13 | 3 | October 19 |
| 1910 | 1 | 2 | 3 | 1 | 2 | 7 | 12 | 13 | 11 | October 29 |
| 1911 | 5 | 0 | 7 | 0 | 9 | 8 | 10 | 15 | 13 | October 29 |
| 1912 | 8 | 1 | 10 | 11 | 7 | 2 | 14 | 12 | ........ | October 16 |
| 1913 | 2 | 2 | 4 | 0 | 5 | 7 | 7 | ........ | ........ | September 23 |
| 1914 | 7 | 3 | 3 | 1 | 4 | 12 | 6 | 12 | 11 | October 27 |
| 1915 | 12 | 8 | 7 | 6 | 14 | 5 | 11 | 8 | ........ | October 10 |
| 1916 | 12 | 2 | 1 | 2 | 4 | 6 | 13 | 6 | ........ | October 11 |
| 1917 | 4 | 8 | 0 | 2 | 6 | 11 | 13 | 8 | ........ | October 9 |
| 1918 | 7 | 7 | 2 | 0 | 3 | 14 | 15 | ........ | ........ | October 1 |
| 1919 | 3 | 0 | 1 | 5 | 6 | 9 | 11 | 10 | 16 | November 13 |
| 1920 | 9 | 6 | 6 | 4 | 9 | 11 | 7 | 9 | 12 | November 12 |
| 1921 | 0 | 0 | 1 | 6 | 4 | 3 | 9 | 13 | ........ | October 14 |
| 1922 | 6 | 4 | 2 | 4 | 7 | 2 | 7 | 5 | ........ | October 13 |
| 1923 | 3 | 0 | 0 | 1 | 8 | 7 | 11 | 6 | ........ | October 7 |
| 1924 | 3 | 6 | 3 | 7 | 3 | 11 | 15 | 14 | 7 | October 23 |
| 1925 | 4 | 2 | 10 | 2 | 2 | 5 | 11 | 9 | ........ | October 10 |
| Av. | 5.8 | 3.4 | 4.0 | 3.7 | 5.9 | 7.3 | 10.5 | 9.1 | 4.4 | October 16 |

*Date temperature fell to 28° or lower.

According to the figures of Table 9, a planting May 15 would have the longest period of favorable weather in some seasons, in others a planting of June 1. When the results are averaged these two planting dates appears to have secured very nearly the same amount of favorable weather during tuber growth, about 40 days, and both somewhat more than any earlier or later plantings.

Altho the average number of cool days during tuber development is the same for these two planting dates, May 15 and June 1, there is less variation from year to year in the numbers in the May 15 column. This comes about from the fact that whenever killing frost occurred in September or early October, the growing season of the June-1 plantings was conspicuously reduced while the May plantings were affected to a lesser degree. As a result, in 8 of the 32 seasons recorded in Table 9, June-1 plantings would have had less than 30 cool days during tuber growth. During the same 32 years the May-15 plantings would have had but 3 seasons with less than 30 cool days of tuber growth. On this basis, it would be concluded that planting May 15 should give more consistently satisfactory yields than planting June 1.

**TABLE 9.—Number of Days With Maximum Temperature Below 80° F. During Tuber Development From Different Planting Dates at Wooster**

Calculated from data of Table 8

| Planted☞ | April 15 | May 1 | May 15 | June 1 |
|---|---|---|---|---|
| Tuber development☞ | June 15 to September 15 | July 1 to September 30 | July 15 to October 15 | August 1 to October 31* |
| 1894 | 16 | 28 | 37 | 37 |
| 1895 | 29 | 34 | 35 | 29 |
| 1896 | 47 | 54 | 65 | 62 |
| 1897 | 39 | 36 | 33 | 27 |
| 1898 | 30 | 33 | 42 | 53 |
| 1899 | 30 | 35 | 30 | 27 |
| 1900 | 17 | 25 | 31 | 43 |
| 1901 | 20 | 31 | 33 | 33 |
| 1902 | 45 | 43 | 55 | 67 |
| 1903 | 40 | 38 | 50 | 54 |
| 1904 | 41 | 45 | 52 | 46 |
| 1905 | 37 | 40 | 54 | 55 |
| 1906 | 22 | 23 | 30 | 26 |
| 1907 | 35 | 41 | 42 | 39 |
| 1908 | 23 | 22 | 20 | 17 |
| 1909 | 32 | 40 | 50 | 47 |
| 1910 | 16 | 27 | 38 | 46 |
| 1911 | 26 | 34 | 49 | 55 |
| 1912 | 39 | 45 | 56 | 46 |
| 1913 | 20 | 25 | 23 | 19 |
| 1914 | 30 | 29 | 38 | 46 |
| 1915 | 52 | 51 | 51 | 44 |
| 1916 | 27 | 28 | 32 | 31 |
| 1917 | 31 | 40 | 40 | 40 |
| 1918 | 33 | 41 | 34 | 32 |
| 1919 | 24 | 32 | 42 | 57 |
| 1920 | 45 | 43 | 46 | 52 |
| 1921 | 14 | 23 | 36 | 35 |
| 1922 | 25 | 26 | 27 | 25 |
| 1923 | 19 | 27 | 33 | 33 |
| 1924 | 33 | 45 | 53 | 57 |
| 1925 | 25 | 32 | 39 | 29 |
| Average | 30.1 | 34.9 | 40.5 | 40.9 |

*End of growing season figured at frost when frost occurred before Oct. 31.

This rough analysis of the Wooster weather leads to a conclusion in essential agreement with the field experiments: plantings about the middle of May should give on the average the highest yields.

*Recommendation based on the Wooster data.*—The conclusion that May 15 is the proper time to plant potatoes is based upon a theoretical growing period five months in length. Actually however the growing period varies, frequently being less than five months. The normal range of variation from season to season and from locality to locality has not yet been determined, but the limited data at hand show that the vegetative period of the Russet Rural may vary at least ten days. To allow for a variation of ten days in the time required to reach maturity, a planting period of ten days, May 15 to 25, is here tentatively recommended for Wooster.

A planting period of May 15 to 25 fulfills all three requirements of a satisfactory planting date. Not only does it encompass the largest amount of favorable weather during tuber development and insure at least a marketable degree of maturity in seasons of early frost, but May planting also very largely escapes the danger from hot soil.

*Effect of hopperburn.*—In deriving the conclusion that May 15 to 25 is the proper time to plant at Wooster, only those small fluctuations in length of the vegetative period occurring in experimental plots have been considered. Under ordinary farm conditions, however, the growing period of the plant is frequently cut short by attacks of insects and diseases. Premature death from hopperburn is particularly common in Ohio. Tilford (40, 41) found at Wooster that unsprayed May plantings died in September from leafhopper injury and the yield was seriously reduced. Similar reductions in yield have been reported from other points in Ohio by Parks and Clayton (33).

From the date-of-planting viewpoint, hopperburn has an effect equivalent to shortening the period of tuber development. Typically, hopperburn first appears about the tuber setting stage. Prior to tuber setting, the injury is not evident even tho hoppers may be abundant. Following tuberization the destruction of the leaves proceeds gradually, premature death resulting several weeks later. Hopperburn shortens the period of tuber growth.

Hopperburn varies in severity from year to year and from locality to locality. The reduction of the effective growing period of the crop varies accordingly. Obviously it is difficult to select a planting date which will, under such conditions, insure favorable weather during the curtailed period of tuber development.

In common practice in northern Ohio when no attempt is made to control leafhoppers, planting is usually deferred until the latter half of June. This practice places tuber setting in late August, and tuber development during the most favorable part of the fall weather. June planting followed by tuber development during September and early October is doubtless preferable to May planting accompanied by premature death from hopperburn in September.

The disadvantages of the common practice of planting in late June and not spraying have been mentioned earlier but are of sufficient importance to be restated here. Aside from the primary consideration, that of the destruction of the leaves from hopperburn, the late planting itself leads to (1) increased shrinkage of seed tubers prior to planting; (2) greater risk of rotting of seed pieces due to hot soil; (3) failure of the growing crop to take the most advantage of any favorable weather in July and August; (4) immature tubers in seasons of early frost.

In spite of these numerous disadvantages from not controlling leafhoppers, spraying has not as yet become an estabished farm practice in potato production in Ohio. Consequently it is necessary to make two distinct recommendations for time of planting—one for the sprayed crop, the other for the unsprayed crop. For the sprayed crop, as was pointed out above, plantings at Wooster should be made between May 15 and 25. For the unsprayed crop, no experimental data are at hand; but current practices and observations indicate that the best planting period is three or four weeks later, that is, about June 10 to 25.

*Recommendations for other points of northern Ohio.*—The recommendations derived for Wooster aim to secure as much cool weather during tuber development as possible. On the same basis, generalizations applicable to all of northern Ohio may be readily derived from the weather records.

An inspection of weather maps (Figs. 6, 7, 8, 9, 11) shows that a large part of northern Ohio has a temperature very similar to that of Wooster. The entire zone with an average frost date (for tender vegetation) between October 1 and 10 has mean monthly temperatures during the growing season which vary but two degrees or less from the Wooster means. Thruout this large area the recommendations for Wooster are applicable with little or no modification. Planting the sprayed crop between May 15 and 25 should be expected to give the highest average yields.

In an area including a portion of Ashtabula and Trumbull Counties frost occurs September 30 or earlier. Here, as may be noted from the weather maps, July and August temperatures are cooler than at Wooster. In effect, then, the favorable potato weather starts earlier in the summer and ends earlier in the fall.

Consequently planting in this district should be a week or two earlier than at Wooster.

In the vicinity of Lake Erie frost is later. Following the same line of reasoning, it would be predicted that the planting date should be correspondingly later. However, it is questionable whether a time of planting based strictly on the date of frost should be applied to this lake zone. The effective growing weather in many seasons comes to an end before killing frost. Near the lake,

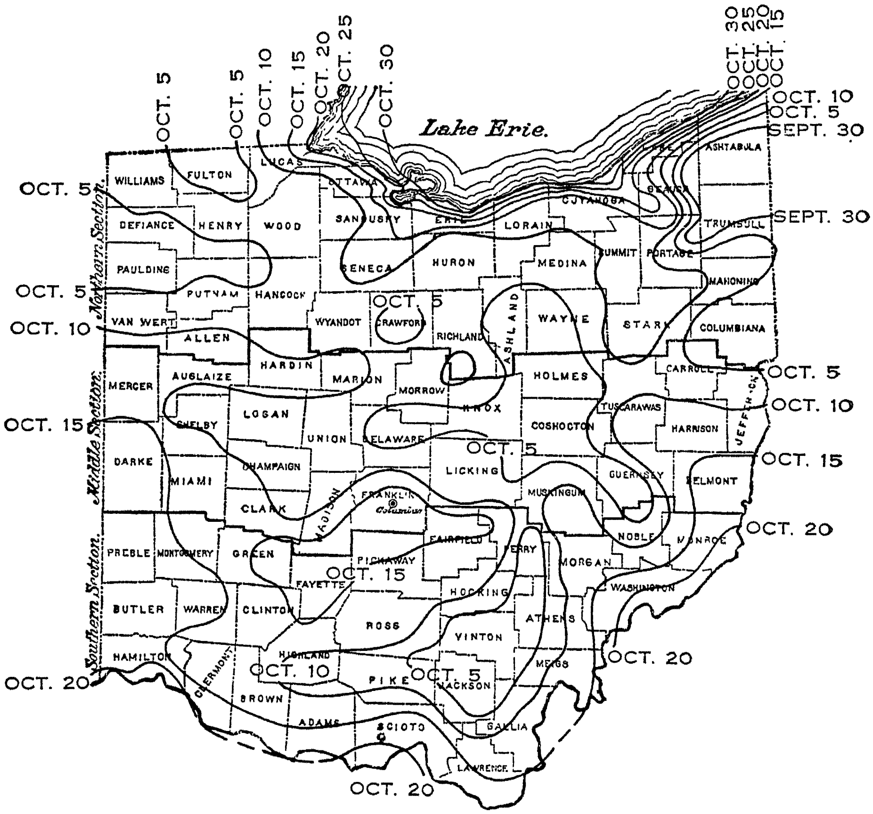


**Fig. 11.—Average dates of the first killing frost in autumn (Alexander, 1)**

frost severe enough to kill potato tops is frequently deferred until November. At the same time, the weather of late October and November may be too cold and cloudy for rapid growth of plants. Altho killing frost is not due until November 2 at Cleveland, the normal temperature drops below 50° F. on October 25, a temperature far below the optimum for potato production. In the Cleveland district, potatoes are usually dug in late October even tho frost has not killed the tops. At the Northeastern Test Farm, 15 miles southwest of Cleveland, a planting June 1 in 1925 outyielded later plantings (Table 10). These facts indicate that the effective growing season in this zone ends sometime in the latter half of October, rather than extending to the date of killing frost. A time of planting so adjusted that maturity coincides with the end of the effective growing season in October would probably give the best yields in this zone. Maturity in late October would follow from planting in late May.

**TABLE 10.—Yield From Different Plantings, Northeastern Test Farm, 1925**

Pounds per plot

| Planted | Russet Rural | Green Mountain |
|---|---|---|
| June 1 | 112 | 107 |
| June 11 | 108 | 92 |
| June 19 | 25* | 50 |

*Low yield due partly to poor stand.

In the west central and southern portions of the State planting should also be deferred until late May. Here the average date of the first killing frost for tender vegetation is between October 10 and 15. The growing season for potatoes probably ends about October 20, and planting the last ten days of May is to be recommended.

*Summary of time of planting the fall crop.*—Thruout northern Ohio the recommended planting dates for the sprayed fall crop are all within the last three weeks of May. The area includes three districts, varying in the average date of frost as reported by the weather bureau, but actual planting recommendations for these three districts are nearly the same:

| Zone with frost date: | Planting period: |
|---|---|
| Before October 1 | May 10-20 |
| October 1 to 10 | May 15-25 |
| After October 10 | May 20-30 |

The planting of the unsprayed crop in all of these zones should be three or four weeks later.

### ADVANTAGES OF EARLY SPRING PLANTING

In deriving the recommendations for time of planting, attention has been focused upon the relation of weather to yield. In drawing the conclusions, economic factors other than yield have been left out of consideration. A number of economic factors, however favor early spring planting. Briefly, some of the advantages of early planting are:

1. The price is higher at the time of harvest. Early plantings mature in September. As shown in Table 11 the September price has averaged 14 cents per bushel higher than the October price.

**TABLE 11.—Farm Prices of Potatoes in Ohio**

From West (45)

| | August | September | October | November |
|---|---|---|---|---|
| 1922 | 1.26 | 1.13 | .95 | .94 |
| 1923 | 1.51 | 1.38 | 1.20 | 1.03 |
| 1924 | 1.20 | 1.11 | 1.05 | .92 |
| Average | 1.32 | 1.21 | 1.07 | .96 |

2. The expense and shrinkage involved in holding seed potatoes during May is eliminated.

3. The risk from losses due to hot soil at the time of planting is avoided.

4. Reduction in yield due to premature ripening, is, in a measure, compensated by the higher price from the earlier harvest.

5. Winter wheat may follow the potatoes, a practice leading to excellent yields of wheat. (See Welton and Morris, 42.)

Under conditions such as prevail at Wooster, where late May planting has exceeded the April plantings in experimental plots by only 8 bushels per acre or less, the economic advantages of early April planting may easily outweigh the small difference in yield. It is not surprising that many of the larger growers in the vicinity of Wooster are planting in April rather than in the latter half of May.

This general situation is probably widely applicable to the zone of northern Ohio with a climate similar to that of Wooster. Altho plantings the latter half of May, would be expected to give the highest average yields, early spring plantings may be more profitable.

The problem faced by the potato producer is that of weighing the advantages of early April planting against the advantages of the fall crop. An important consideration in analyzing this problem is the nature of the fall weather itself. Where the fall weather varies widely from year to year, as at Wooster, with consequent variation in the yield of late May plantings, it may not be sufficiently favorable to weigh heavily against the advantages of early planting. On the other hand, where the fall weather is more consistent, as in the zone modified by Lake Erie, the fall crop is less speculative and more satisfactory. Consequently, in the lake zone early planting is rarely practiced.

## CONCLUSIONS AND RECOMMENDATIONS

The recommendations derived from the evidence at hand are summarized in Figure 12.

Two general principles underlie these recommendations:

1. Early crops, whether of early or late varieties, are planted as soon as the soil is warm enough to insure germination.

2. The time of planting the fall crop is selected so that maturity coincides with the close of the growing season. The actual planting date, then, depends upon the length of the vegetative period of the crop and upon the date of the end of the growing season.

**Precautions.**—In applying these principles and recommendations to practical farm conditions, a few precautions must be heeded:

1. The planting dates for the fall crop apply only to Russet Rural and varieties with a similar growing period. Varieties maturing later should be planted correspondingly earlier, and earlier maturing varieties should be planted later.

2. Unsprayed crops frequently die prematurely from hopperburn. The effect is comparable to shortening the growing period of the crop. Consequently delaying planting of unsprayed fall crops is here recommended. But late planting has several disadvantages and is not a substitute for spraying. It is an expedient to be followed only where leafhoppers cannot be controlled.

3. Planting in hot soil is to be avoided; hot soil induces a rotting of the seed pieces.

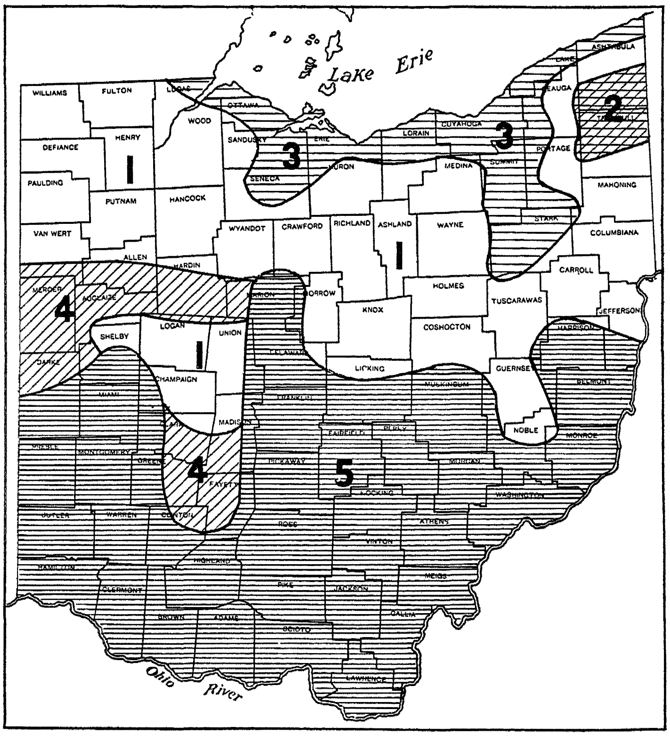


**Fig. 12.—Regions of Ohio based upon the time of planting potatoes**

**Recommendations for Russet Rural:**

| | Date of planting fall crop | | Date of early planting | Average frost date |
|---|---|---|---|---|
| | Sprayed | Unsprayed | | |
| Region 1. | May 15-25 | June 10-25 | April 5-15 | Oct. 1-10 |
| Region 2. | May 10-20 | June 5-20 | April 10-20 | Before Oct. 1 |
| Region 3. | May 20-30 | June 15-30 | * | After Oct. 10 |
| Region 4. | May 20-30 | June 15-30 | April 1-10 | Oct. 10-15 |
| Region 5. | Early varieties predominate. Rural varieties when grown should be planted about the same time as in Region 4. | | | |

*No recommendation.

## SUMMAR


In northern Ohio the Rural group of varieties predominates, and the growing season is longer than these varieties require.

The determination of the best time to plant is primarily an attempt to fit the growing period of the crop to the most favorable weather.

The literature indicates that tuber growth is retarded by high temperatures, such as occur during the summer in Ohio. High temperature in Ohio appears to depress potato yields more than drouth. Therefore to obtain highest yields it is necessary to secure as much cool weather during the time of tuber development as possible.

With the Rural varieties this is accomplished by planting at such a time that tubers develop during the cool weather of the fall and maturity coincides with the end of the growing season.

Field experiments of four seasons show highest yields from plantings made between May 13 and June 2.

An analysis of the Wooster weather records indicates that the average date of frost severe enough to kill potato tops is October 16. Plantings between May 15 and 25, adequately sprayed, would mature about October 16 and thus theoretically give the highest average yields.

Where spraying cannot be followed, the crop frequently dies prematurely from hopperburn. As the growing period of the crop is thus shortened it is suggested that unsprayed plantings should be put in three or four weeks later than sprayed crops.

A number of economic factors, particularly price at harvest, favor early April planting. At Wooster these factors frequently outweigh the advantage in yield to be gained from May planting. Where the fall weather is more favorable for potatoes than at Wooster, early planting is less common.

Detailed recommendations for the various sections of northern Ohio are summarized on page 381. In general, planting the last three weeks in May, to be followed by thoro spraying, is recommend.

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